SOCAN SOUTH CAROLINA/GEORGIA STAKEHOLDER WORKSHOP

7/27/18

Workshop Report

SOCAN
Southeast Ocean and Coastal Acidification Network

Ocean Conservancy®

SOCAN SOUTH CAROLINA/GEORGIA STAKEHOLDER WORKSHOP

SUMMARY

The Southeast Ocean and Coastal Acidification Network (SOCAN), in conjunction with Ocean Conservancy, held a half-day acidification stakeholder workshop in Charleston, South Carolina on July 27, 2018. Attendees included stormwater managers, oyster growers, fishermen, water quality experts and cultural representatives. The workshop served as the first public forum for acidification stakeholders in South Carolina and Georgia.

Coastal acidification in the U.S Southeast is a water quality issue and a consequence of changes to freshwater delivery, land use change and nutrients and organic matter entering local water ways. The impacts of *coastal* acidification in South Carolina and Georgia may be more imminent than those from oceanic absorption of atmospheric carbon dioxide. With limited research and monitoring in the region, the workshop focused on potential evidence or causal agents of acidification and next steps to engage stakeholders in moving research and monitoring forward.

The objectives of the workshop were to:

- Introduce coastal acidification, its linkages to water quality and discuss potential impacts and solutions with stakeholders;
- Understand how water quality has changed over time in Georgia and South Carolina and the relationship between these changes and coastal acidification
- Discuss impacts of changing water quality and acidification on coastal resources and priorities to address these issues in important habitat and business operations of particular concern
- Prioritize research needs and discuss opportunities for partnerships and leveraging of resources to move acidification monitoring efforts forward

The workshop aimed to consider acidification with concurrent water quality issues while also discussing how changes in water quality have impacted or could impact coastal resources. The scarcity of research and monitoring limits the ability to directly attribute changes in coastal resources to acidification but the workshop provided a platform for sharing perspectives of how shellfish habitat has changed over time.

Though it is clear the coastal regions of South Carolina are undergoing rapid development and changes in water quality, there is not enough data to determine acidification trends. Therefore, much of the workshop was spent considering other water quality changes, such as trends in oxygen, and how these may relate to acidification.

Long term monitoring at the Gray's Reef National Marine Sanctuary (GRNMS) offshore of Georgia has shown seawater carbon dioxide concentrations increasing at a faster rate than the atmosphere, indicating an additional source of carbon. Monitoring inshore of GRNMS at Sapelo Island has also shown long-term trends of increasing carbon dioxide, likely from enhanced respiration of organic matter (breakdown of carbon in marsh systems). Unlike many other systems in the United States, the relatively well-mixed estuaries of South Carolina and Georgia do not appear to have eutrophication-based acidification.

Next steps from the workshop are focused on how to build momentum for research and monitoring in South Carolina and Georgia as there is a clear gap in data.

PROCEEDINGS

Twenty-nine workshop attendees included representatives of SC Department of Natural Resources (DNR) and the Department of Environmental Health and Control (DHEC), South Carolina Aquarium, Charleston Waterkeeper, Town of Bluffton Stormwater Quality Program, representatives of the Gullah/Geechee, commercial shellfish harvesters, and many more (see *Attendee List*, Appendix II). The workshop began with an introduction to SOCAN and an overview of the current state of knowledge of acidification in SC and GA. Scott Noakes (University of Georgia) presented on water chemistry monitoring at Gray's Reef National Marine Sanctuary and Sapelo Island, GA. Next, Erik Smith (North Inlet Winyah Bay NERRS/Baruch Institute), discussed National Estuarine Research Reserve System (NERRS) data as it relates to oxygen and pH relationships and how long-term trends interact with shorter term variability. Lastly, Ryan Ono (Ocean Conservancy), reviewed the opportunities at state and local levels to address acidification and support momentum for research in our region.

The second half of the workshop was discussion-based and targeted deep contextual understanding of coastal resources, changing water quality and potential intersections with coastal acidification. Stakeholders discussed their relative concerns, if any, for changes in shellfish habitat, community relations with respect to water quality and avenues forward for collaborative momentum.

SETTING THE LOCAL CONTEXT

Acidification in the U.S. Southeast: Is it a Problem?
Presentation by Leslie Wickes, SOCAN Project Manager

Leslie Wickes (SOCAN) reviewed the chemistry of ocean and coastal acidification and then focused on the contributing factors of coastal acidification *potentially* relevant to the U.S. Southeast. These include:

1. **Low aragonite saturation rivers** with high discharge volumes[1]
2. **Increases in freshwater delivery** from impervious surfaces and climate change driven heavy precipitation events that can lead to low pH river plumes
3. **Eutrophication** that can lead to increased primary production that, when remineralized, can cause increases in carbon dioxide and decreased pH in subsurface waters
4. **Coastal ocean warming** increases breakdown of organic matter and respiration-driven increases in carbon dioxide[2]

After each of these factors were introduced there was a review of what is currently known about the effects of acidification on species relevant to Georgia and South Carolina, focusing on eastern oysters, hard clams and blue crabs:

- While the effects of acidification on the eastern oyster have been relatively well studied, there are few examples of research on these stocks from the U.S. Southeast. Studies in other regions have found significant vulnerabilities in larval and juvenile shell mineralogy as well as some effects on metabolic rates[3].
- The most compelling evidence of the effects of acidification on eastern oyster populations in the U.S Southeast was recent research[4] showing compromised reproduction for North Carolina oysters. Though oysters were resilient at open ocean projections of pH change (pH 7.5, pCO_2 2260 μatm), the "severe" treatment (pH 7.1, pCO_2 5584 μatm) showed significant effects to gametogenesis with oogenesis particularly vulnerable. Selective pressures on female oysters could cause seasonal bottlenecks with declines in gametogenesis. These conditions are not uncommon for seasonal acidification of coastal habitats and were reported by Scott Noakes in his monitoring at Sapelo Island, GA.
- Research has shown there is no effect of acidification on metabolic rate of hard clams in laboratory experiments, but similar to oysters, acidified conditions resulted in changes to mechanical properties of the clams' shells[5].
- Transgenerational exposure of New York hard clams found that offspring were more vulnerable to low pH and additional stressors when compared to the parent generation[6]

[1] Jiang L-Q, Cai W-J, Feely RA , Wang Y, Guo X, Gledhill DK, Hu X, Arzayus F, Chen F, Hartmann J, Zhang L (2010). Carbonate mineral saturation states along the U.S. East Coast. Limnology and Oceanography, 55.

[2] Reimer JJ, Wang H, Vargas R, & W-J Cai (2017). Multidecadal fCO_2 increase along the United States southeast coastal margin. Journal of Geophysical Research: Oceans, 122, 10,061–10,072.

[3] Beniash E, Ivanina A, Lieb NS, Kurochkin I, Sokolova IM (2010) Elevated level of carbon dioxide affects metabolism and shell formation in oysters *Crassostrea virginica*. Mar Ecol Prog Ser 419:95-108. 1

[4] Boulais M, Chenevert KJ, Demey AT, Darrow ES, Robison MR, Roberts JR, and A Volety (2017). Oyster reproduction is compromised by acidification experienced seasonally in coastal regions. Scientific Reports 7: 13276.

[5] Gary H. Dickinson, Omera B. Matoo, Robert T. Tourek, Inna M. Sokolova, Elia Beniash (2013). Environmental salinity modulates the effects of elevated CO_2 levels on juvenile hard-shell clams, *Mercenaria mercenaria*. Journal of Experimental Biology 2013 216: 2607-2618.

[6] Griffith AW, Gobler CJ (2017). Transgenerational exposure of North Atlantic bivalves to ocean acidification renders offspring more vulnerable to low pH and additional stressors. Scientific Reports. 7:11394.

- While there has not been research on acidification effects on blue crabs in the Southeast, research from other regions has shown mixed effects. Glandon et al. noted no effects of pCO_2 on growth and food consumption[7]. In a follow up study, they found counteractive effects of pCO_2 and temperature on juvenile blue crabs from Chesapeake Bay with potential tradeoffs between carapace thickness and chemistry[8].

The presentation evaluated the often-proposed idea that estuarine dynamics confer resilience to acidification. It is likely that extreme coastal conditions have fostered genetically diverse populations that are consequently resilient to some aspects of changing conditions. Despite this resilience, research has found that the magnitude and rate of change can affect how organisms respond to acidification. A recent study pointed out that diurnal exposure to low pH and/or low DO did not mitigate the negative effects of acidification or hypoxia for larval bivalves[9].

Our Changing Water Chemistry: Offshore and Coastal Environments Presentation by Scott Noakes, University of Georgia

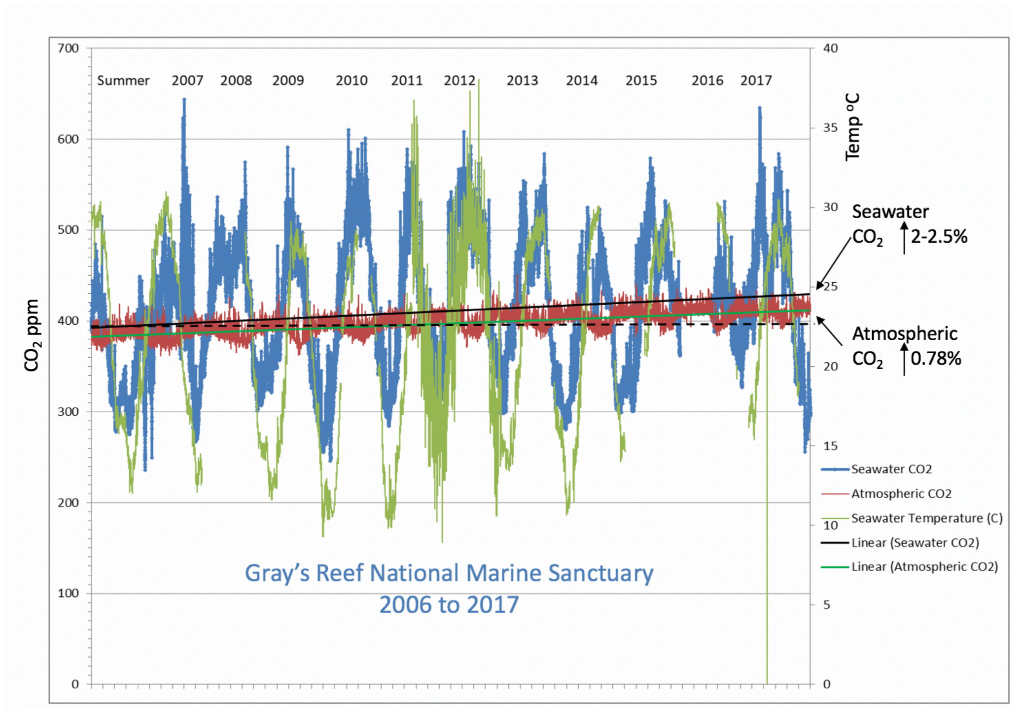

Figure 1. Carbon dioxide concentrations and temperature at Gray's Reef National Marine Sanctuary showing seawater concentrations (blue) have increased by 2-2.5% while atmospheric CO_2 (green) has increased by 0.78% at the same site. Credit: Scott Noakes, University of Georgia

Scott Noakes (University of Georgia) presented research from the Gray's Reef National Marine Sanctuary (GRNMS) ocean acidification monitoring buoy and monitoring inshore at Sapelo Island. Carbon dioxide increases in subsurface seawater at GRNMS exceed those measured in the atmosphere, pointing to

[7] Glandon HL and TJ Miller (2016). No effect of high pCO2 on juvenile blue crab, *Callinectes sapidus*, growth and consumption despite positive responses to concurrent warming, ICES Journal of Marine Science. 74(4): 1201–1209.
[8] Glandon HL, Kilbourne KH,Schijf J,Miller TJ (2018). Counteractive effects of increased temperature and pCO2 on the thickness and chemistry of the carapace of juvenile blue crab, *Callinectes sapidus*, from the Patuxent River, Chesapeake Bay. Journal of Experimental Marine Biology and Ecology. 498:39-45.
[9] Clark, H., & Gobler, C. (2016). Do diurnal fluctuations in CO2 and dissolved oxygen concentrations provide a refuge from hypoxia and acidification for early life stage bivalves? Marine Ecology Progress Series. 558: 1–14.

additional sources of carbon (Figure 1). Rapid swings in seafloor bottom carbon dioxide and pH are attributed to storm events that likely cause release of high CO_2 porewater from sediments. These rapid changes are orders of magnitude higher than baseline variation (Figure 2).

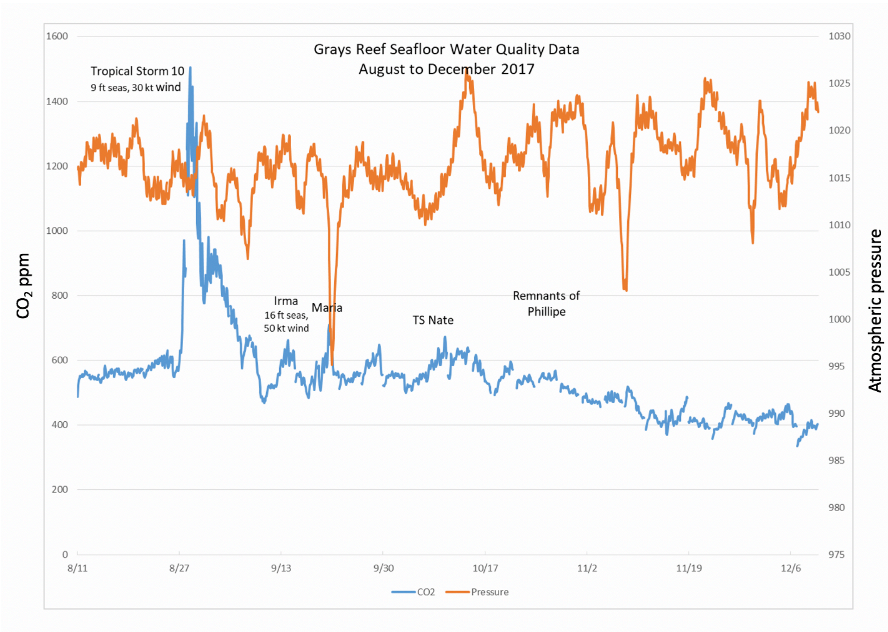

Figure 2. Seafloor carbon dioxide (CO_2) concentrations and atmospheric pressure from August to December 2017 at Grays Reef National Marine Sanctuary showing rapid changes in seafloor CO_2 corresponding to passing storm events. Credit: Scott Noakes.

Additional opportunistic monitoring inshore of GRNMS at Sapelo Island has shown carbon dioxide concentrations at low tide can surpass 4,000-5,000 ppm. This work, in partnership with Charlie Phillips at Sapelo Sea Farms, reveals that these extreme conditions coincide with timing of seeding, which operationally takes place at low tide. Charlie Phillips reports mortality of 30-40% of seeded clams, though there is no direct research to link acidified conditions with mortality at this location.

Dr. Noakes highlighted that organisms chose to live in these extremely harsh conditions and are likely adapted to them. Though adult organisms appear to be resilient, laboratory research has shown negative effects for larval organisms at ~900ppm and if timing of extreme low pH conditions coincides with reproductive events, there could be serious impacts[4]

Quantifying Metabolically Driven pH & Oxygen Fluctuations in Nearshore Habitats Presentation by Erik Smith, North Inlet-Winyah Bay NERR/ University of South Carolina

The presentation by Erik Smith sought to consider potential acidification-driven shifts in near-shore coastal waters in the context of natural pH variability and the factors that drive this variability. The presentation centered around the publication by Baumann and Smith[10] that compiled and compared pH, DO, temperature, salinity, nutrients and chlorophyll data from a diversity of shallow-water sites in the National Estuarine Research Reserve System (NERRS). Unlike open ocean interannual trends that show consistent declines in pH, Baumann and Smith concluded nearshore environments are strongly influenced by biological production and respiration balances with no consistent interannual trends in pH across individual sites from 2002 to 2016.

[10] Baumann, H. & Smith, E.M. (2018). Quantifying Metabolically Driven pH and Oxygen Fluctuations in US Nearshore Habitats at Diel to Interannual Time Scales. Estuaries and Coasts (2018) 41: 1102.

For Southeast sites, the authors found a statistically significant decrease in pH at the North Carolina (NOC) site and no detectable trend in North Inlet- Winyah Bay (NIW) or ACE Basin (ACE). Fluctuations in pH at ACE Basin and NIWB exceeded those from all other sites, which was attributed to a combination of high primary productivity and large inputs of dissolved inorganic carbon (DIC) from the extensive intertidal marshes adjacent to these sites.

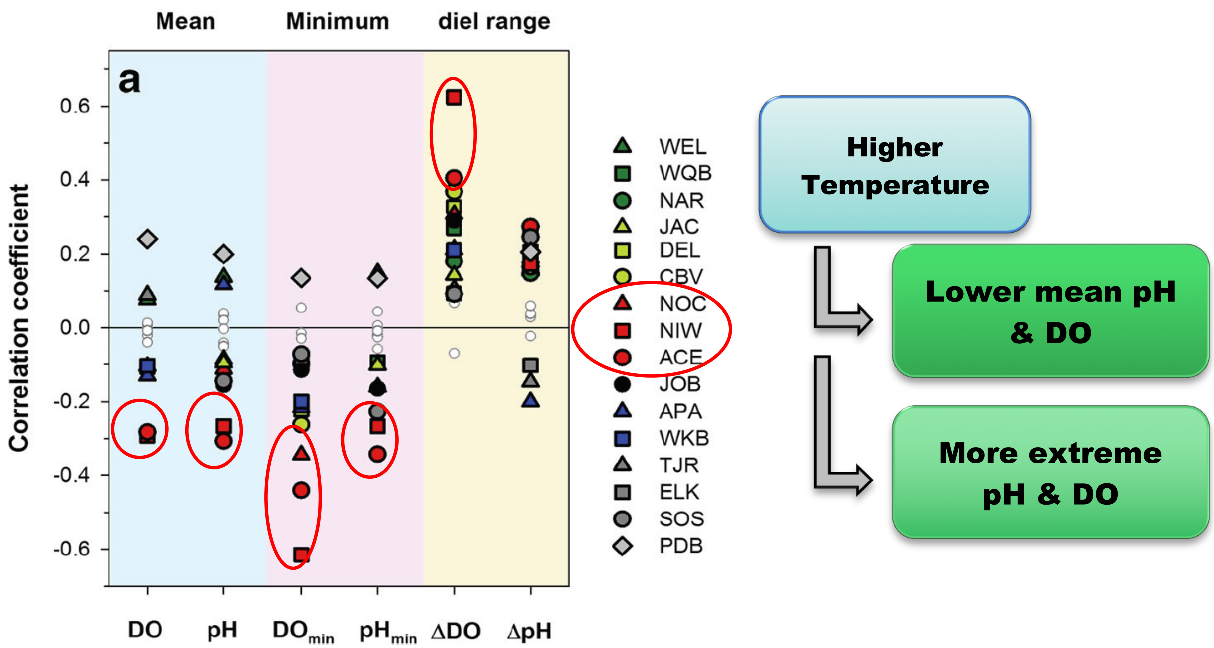

Figure 3. Correlation of weekly anomalies of temperature with weekly anomalies of dissolved oxygen (DO) and pH at NERRS sites. Red circles are shown around Southeast NERRS sites, including North Carolina (NOC), North Inlet-Winyah Bay (NIW) and ACE Basin (ACE). Credit: Baumann and Smith (2018), modified by Erik Smith.

Nearly all estuaries in the study were found to be net heterotrophic, meaning that the estuaries were a source of carbon dioxide to the atmosphere, driven by respiration of the large amounts of organic matter entering these estuarine systems. Warming is anticipated to favor respiration over photosynthesis, enhancing the breakdown of this organic matter. Higher temperatures that increase respiration are correlated with lower pH and dissolved inorganic carbon. Increasing temperatures are also correlated with an increase in the magnitude of diel ranges (more extremes) in pH and dissolved oxygen and this pattern was particularly dominant in the Southeast estuaries (Figure 3).

The only site in the study to show a positive correlation between nutrients and chlorophyll (i.e. primary production) was North Inlet-Winyah Bay (NIWB). The authors attributed this counterintuitive lack of relationship in the other estuaries to the high turnover rate of inorganic nutrients as a result of the estuaries being well-mixed and highly productive. NIWB was also the only site to also have a positive correlation between inorganic nutrients and pH over time.

A key finding of the NERRS research is the unifying and predictable relationship between pH, salinity and oxygen within and across a large diversity of shallow water estuarine systems. Similar algorithms have been established in other regions and would greatly enhance our understanding of baseline variability in pH without empirical measurements. Efforts should be made to extend these algorithms to other Southeast estuaries to track potential changes in production – respiration balances that could lead to coastal acidification.

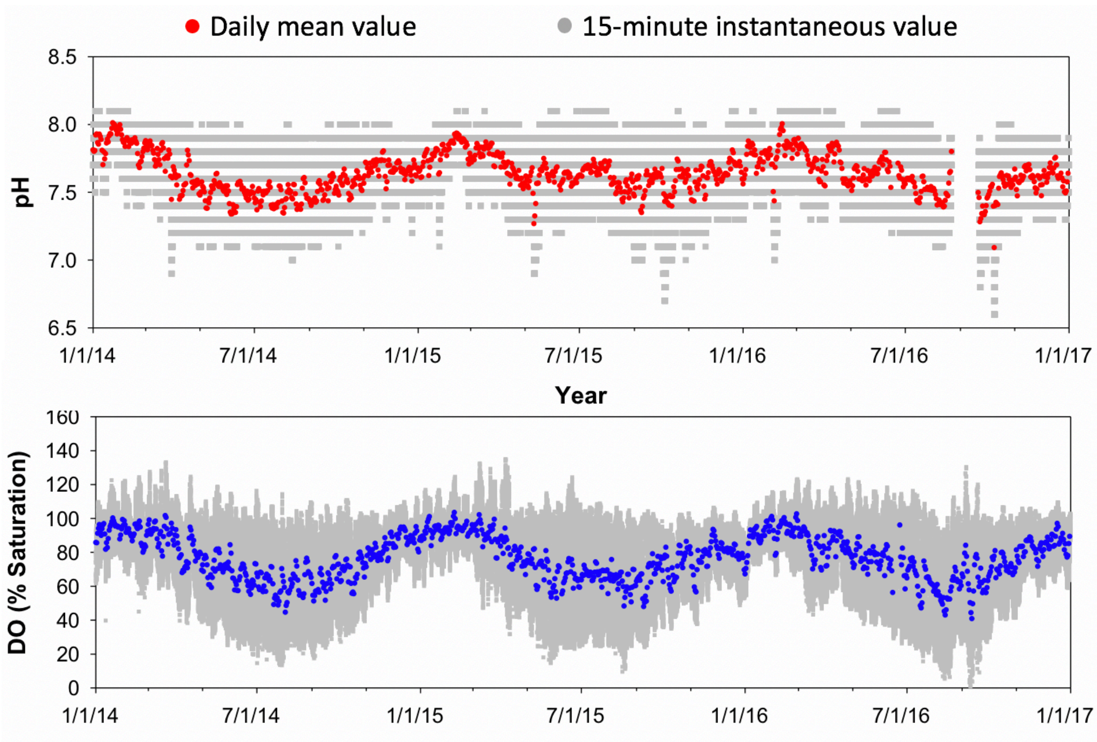

Figure 4. Daily means (red/blue) and 15-minute instantaneous values (grey) for pH (top) and dissolved oxygen (bottom) from 2014 to 2017 at North Inlet-Winyah Bay. Credit: Erik Smith.

An Ounce of Prevention for Coastal Water Quality and Acidification
Presentation by Ryan Ono, Ocean Conservancy

In the Southeast US, coastal acidification has not measurably harmed coastal resources as it has in other parts of the country.[11] Yet there is a growing recognition by scientists, managers and ocean industry leaders that the impacts of coastal acidification alone or in conjunction with other environmental stressors will have negative impacts to coastal businesses, ecosystems and communities in the region. The threat of losses to coastal communities and the continued absence of large reductions in global carbon dioxide emissions have spurred academics[12] and advocacy groups[13] to identify proactive steps

[11] Barton, Alan, et al. "Impacts of coastal acidification on the Pacific Northwest shellfish industry and adaptation strategies implemented in response." *Oceanography* 28.2 (2015): 146-159.
[12] Kelly, Ryan P., et al. "Mitigating local causes of ocean acidification with existing laws." *Science* 332.6033 (2011): 1036-1037.

for coastal stakeholders and policymakers to address acidification at a more local level. Many of these steps have already been taken around the country by various stakeholders. Examples of non-legislative actions are presented here, categorized by type and ordered by degree of escalating difficulty, complexity and cost.

Educate

Given the differing levels of understanding in any community, educating ocean and coastal stakeholders about ocean and coastal acidification may be an appropriate and inexpensive first step. Nearly any concerned citizen can share a news article using email, host a meeting, write a blogpost or opinion news article. By doing so they can define acidification in an accessible way, understand the threat, and discuss possible solutions. These actions do not cost much money nor do they require an advanced degree to organize, and they even can be conducted online as well. Scientists are often key participants in this work, as concerned citizens or local experts. More involved and expensive measures could include creating a film on acidification[14] or creating infographics to not only educate others, but also highlight acidification as a threat that needs attention.

Science assessment and closing knowledge gaps

Unfortunately, many parts of the country, including the southeast US, do not have a robust set of water chemistry data or experimental results related to ocean acidification which could better inform coastal water management decisions. Stakeholders wishing to know more about ocean acidification's impacts on their local waters ask experts what is known and unknown, yet knowledge gaps are common even among experts. Science assessments by scientists, natural resource managers and other experts are often needed to define the state of the local acidification science, and lay out plans to close gaps in understanding. Often these plans include increased water chemistry monitoring in areas of concern, and conducting experiments on local species of concern, particularly those of high economic or ecological value such as blue crab, oysters, clams, and finfish. Activities as simple as convening experts and summarizing the science to actions as involved as expanding monitoring and experiments can range in price from $1,000 to $1,000,000 per year, and take a few months to multiple years or more for projects to produce results.

Support Businesses

Individuals who rely on predictable water chemistry for their jobs and businesses, such as shellfish growers and fishermen, often see changes to the environment first. They often feel the economic impacts most severely among all coastal stakeholders. For those reasons businesses such as the shellfish hatcheries in the Pacific Northwest have become among the strongest supporters for action to address acidification. In some rural, coastal areas, the seafood and shellfish industry play important

[13] Cooley, Sarah R., et al. "Community-level actions that can address ocean acidification." *Frontiers in Marine Science* 2 (2016): 128.

[14] O'Chang Studios. "A Climate Calamity In The Gulf Of Maine Part 2: Acid In The Gulf." Posted 9 Mar 2016. Accessed 7 Sep 2018. https://www.youtube.com/watch?v=ZimEBFw1Q7c

economic and cultural roles which can be disproportionately harmed by acidification. Actions to protect the jobs and cultural heritage of these areas can include publicly funding and supporting the installation and use of water chemistry monitoring equipment and seawater buffering inside shellfish hatcheries. Supporting the construction of additional hatcheries in diverse areas helps lower industry risk so any single environmental hazard, such as a hurricane or acidification event, does not debilitate the local economy and community. A single monitoring device could cost between $1,000 and $50,000 while a hatchery may cost upwards of $3,000,000.[15]

Manage for Resilience

Communities that wish to create more resilient ecosystems as a long-term protection against coastal acidification will find these actions take more time, community willpower, and funding to successfully complete. Involving other interest groups, management agencies and communities will also be necessary. Action could include factoring acidification into fisheries stock assessments, which may lower harvest quotas for the current fishing season in order to protect long-term stock levels. Restoration of oyster reefs, coral reefs and seagrass beds is another type of action falling into this environmental resilience category, because they rebuild healthy habitats and may reduce acidification locally. Practicing smart urban growth to prevent sprawl and enacting environmentally friendly land-use policies would also be included as ways to reduce nutrient runoff pollution to local waterways. These actions require increased education and political will on the part of communities to dedicate public resources and funds for long-term investments in natural infrastructure, such as reefs. As indirectly related as acidification may be to these prescriptions, acidification does not necessarily need to be the sole reason for taking action. Oyster and coral reef restoration can be justified by hurricane and storm surge protection, coastal erosion protection and fish habitat creation the structures offer to coastal communities. Oysters and shellfish also help clean local waters by filtering excess nitrogen and phosphorus. Indeed, communities have already been investing in these activities[16], yet not with the goal of addressing acidification.

Cut Local Acidification

Cutting acidification locally addresses the issue most directly. Actions include enforcing existing water quality regulations, enhancing wastewater treatment at public works facilities, fixing leaking septic tanks and sewer systems, reducing lawn overfertilization and cutting local carbon dioxide emissions. These are the most difficult actions to undertake and few communities have done so with acidification as the primary motivation.

Ensuring clean water, preventing algal blooms, and even addressing climate change usually serve as the justification for some of these expensive, long-term and sometimes politically difficult pursuits. Yet

[15] Wold, Amy. "New Hatchery Likely to Double Oyster Production at LSU's Grand Isle Site, Be Something 'Every Citizen in Louisiana Will Benefit from'." The Advocate, 8 Dec. 2015, www.theadvocate.com/baton_rouge/news/article_d7dd440b-64c7-59e9-9d12-10da55dccaf4.html.

[16] Grabowski JH Peterson CH. 2007. Restoring oyster reefs to recover ecosystem services. Pages 281–298 in Cuddington K, Byers JE, Wilson WG, Hastings A, eds. Ecosystem Engineers: Plants to Protists. Elsevier.

these actions would result in the most direct, immediate and likely significant reduction in local acidity levels.

The actions described above and in Figure 5 help maintain or improve coastal water quality and prevent the negative consequences of acidification to the benefit of local businesses and ecosystems. As investments in preventative maintenance, these grouped actions build upon each other with greater positive impact. The actions that cut local acidification are often initiated in communities after other actions are taken because of the education, political will, and financing required for success. As difficult as these may be, some efforts already in progress address complicated environmental stressors such as harmful algal blooms, climate change, and coastal erosion via living shorelines have the positive externality of also reducing or mitigating acidification. For future actions, acidification may then serve as an additional reason to act for the benefit of coastal communities.

Figure 5. Community-level actions to address acidification. Credit: Ocean Conservancy adapted from Cooley et al. 2016

DISCUSSION

What water quality changes are we seeing, and how might they be interacting with acidification?

The concerns of stakeholders centered around land use change in the rapidly growing Southeast coastal areas and the subsequent consequences of over-fertilization and fecal contamination. Clemson Extension's Carolina Clear program has partnered with local communities and management divisions, including the Town of Bluffton's Stormwater and Watershed Management Division, to engage and educate the public on these issues. In addition, one of the highest priority issues in the region is coastal flooding and sea level rise. Linking acidification to issues that are already on the public radar will greatly increase the momentum in moving acidification research and awareness forward.

Over-fertilization can lead to eutrophication enhanced acidification through bacterial respiration of algal blooms. While there has not been extensive research in SC/GA to evaluate this linkage, available data from well-mixed estuaries in the region suggests it is does not follow traditional nutrient-chlorophyll-pH dynamic[10] seen in other eutrophication studies[17]. Current evidence suggests the more likely culprits are increased organic loading and increased respiration as a function of warming. When coastal marsh ecosystems warm, productivity and subsequent carbon export from the marsh increases. Organic matter is broken down by bacterial organisms locally increasing respiratory carbon dioxide.

There have not been enough studies to clearly connect sea level rise and coastal flooding with acidification. One possibility, based on evidence from small spatiotemporal scale studies (e.g. tidal cycles), is that as sea level rises, water will mix further into marshes, which could cause more CO_2 rich pore water to mix and enter the water column. It could also increase the amounts of labile organic matter, resulting in large pulses of CO_2 and decreases in pH as the organic matter is rapidly respired.

It will be important to consider pulse changes in water chemistry and how these may interact with long term consequences of shellfish populations. Workshop attendees noted shellfish beds have been in 8ppm salinity due to rainfall and freshwater delivery- these pulse events could have strong impacts if timing coincides with reproduction and recruitment events.

What changes are we seeing to coastal resources?

There was no consensus among shellfish harvesters and growers as to how recruitment and health of shellfish have changed over time. Ed Atkins (Gullah Geechee Fishing Association) noted marked loss of oyster habitat, lack of recruitment and even stated "we can't get the shell to survive," while attenees from Charleston Oyster Company stated that they do not believe oyster recruitment is a current issue. Dave Belanger, a local clamer, noted the complete disappearance of the wild clam populations and reduction in wild spat, speculating changes in water quality are to blame, particularly with respect to

[17] Cai W-J, Xinping H, Huang W-J, Murrell MC, Lehter JC, et al. (2011). Acidification of subsurface coastal waters enhanced by eutrophication. Nature Geosciences. 4:766-770.

pesticide and herbicide applications. Stakeholder perception of changes seem to be at least partially attributed to their length of time in the industry and age in observing these changes.

What are the priority monitoring locations for South Carolina and Georgia and what opportunities do we have to move this monitoring forward?

Cost is prohibitive in establishing a new monitoring program and opportunities should be strategically leveraged to launch monitoring in South Carolina. The only likely scenario is to add new sensors to existing platforms. The Southeast Coastal Ocean Observing Regional Association (SECOORA) recently installed a platform in Charleston Harbor. Charleston Harbor is a coastal epicenter that offers opportunities for public awareness and engagement. Furthermore, it provides a paired site to existing monitoring in undeveloped areas near Sapelo Island and the NERRS sites (pH only). Erik Smith countered that adding a sensor to Charleston Harbor would provide very little information with regards to attribution of acidification as water is relatively well mixed from the two river systems, the Cooper and Ashley Rivers, and it is not proximal to seagrass and oyster habitat.

Utilizing lower quality pH data, as well as the strong relationship between pH and oxygen established in Baumann and Smith[10], existing water quality stations in the region could be used identify hotspots for future monitoring efforts. New efforts should focus on evaluating the full coverage of relevant water quality data (e.g. Department of Health and Environmental Control, United States Geological Survey. College of Charleston, Charleston Waterkeeper) to identify these likely hotspots. If the Baumann and Smith[10] pH and oxygen relationship can be confirmed for a wider set of spatiotemporal coverage, these relatively easy parameters to measure could be captured by citizen science programs and used to estimate carbonate chemistry. In addition, the linkages between pH and oxygen may provide in indirect opportunities to include acidification in existing water quality management. It is also important to note that upstream monitoring will provide valuable insight to downstream acidification, as freshwater delivery and exports from land are the important drivers.

What are the cultural concerns of our region as they relate to acidification? How can we better communicate acidification in our region?

Communicating acidification in this region is in its infancy and concepts have not been developed fully to provide cohesive messaging. While there is a broad base of knowledge for how best to communicate acidification, messaging should be intentional, fitting the cultural context of the region along with resident's priority concerns. There is no one fits all approach and even within a relatively small region in South Carolina, messaging must be tailored to best resonate with communities. Queen Quet noted the importance of "educating, not managing, people" as we move forward with engagement and education. Additionally, as coastal acidification is driven in our region by land-based sources, there needs to be some degree of coordination inland.

Next steps and final thoughts:

Additional research to understand and monitor acidification is required before communicating acidification as a concern to Georgia and South Carolina residents. Similar to the Northeast and Midatlantic, there may be opportunities to leverage funding from NOAA's Ocean Acidification Program and the Southeast Sea Grant offices for research. SOCAN should also investigate opportunities with philanthropic private funders and align work with other non-profits working in the region.

Coastal Georgia and South Carolina have extensive pristine estuarine habitats. These habitats offer ample opportunities for comparative studies and research that utilizes natural gradients. There are strong cultural and economic ties with these coastal areas and their proximity to more developed regions serves as a reminder to residents to protect the ecosystems they value.

APPENDIX I: AGENDA

10:00-10:15	**Check In**
10:15 – 10:20 Speakers: Leslie Wickes & Ryan Ono	**1. Welcome, Overview of Meeting Objectives, and Introductions** <u>Objective:</u> Welcome everyone, review agenda and objectives. Gather additional thoughts from attendees about objectives.
10:20-10:40 Speaker: Leslie Wickes	**2. Introducing SOCAN and acidification in the U.S. Southeast** <u>Objective:</u> Introduce SOCAN- past, present and future and summarize existing acidification research in Georgia and South Carolina <u>Activities/Interactions</u>: ● Leslie gives short presentation on SOCAN ● Discuss how other regional networks work with stakeholders ● Summarize research on both acidification chemistry and potential impacts in Georgia and South Carolina
10:40-11:00 Speaker: Scott Noakes	**3. Our changing water chemistry: offshore and coastal environments** <u>Objective:</u> Introduce data from the Gray's Reef National Marine Sanctuary mooring and preliminary research at Sapelo Island, GA
11:00-11:20 Speaker: Erik Smith	**4. Quantifying Metabolically Driven pH & Oxygen Fluctuations in Nearshore Habitats** <u>Objective</u>: Discuss what NERRS SWMP data tell us about the potential for ocean acidification impacts in estuaries
11:20-11:40 Speaker: Ryan Ono	**5. An Ounce of Prevention for Coastal Water Quality and Acidification** <u>Objective:</u> Discuss opportunities for community level action for acidification
11:40-12:20	**6. Q&A with panel (Leslie Wickes, Scott Noakes, Erik Smith, Ryan Ono)**
12:20-13:00	**Break and gather lunch**
13:00-13:40	**7. Discussion 1: What water quality changes are we seeing, and how might they be interacting with acidification?**
13:40-14:20	**8. Discussion 2: Managing risk: shellfish, acidification and how to prioritize monitoring**
14:20-15:00	**9. Discussion 3: Next steps: Needs, opportunities, and partnerships in South Carolina and Georgia**
15:00-16:00	**Open Discussion**

APPENDIX II: PARTICIPANT LIST

Name	Affiliation	Email Address
Al George	South Carolina Aquarium	ageorge@scaquarium.org
Amy Scaroni	Clemson Extension	ascaron@clemson.edu
Andrea Margiotta	South Carolina Aquarium Good Catch	amargiotta@scaquarium.org
Caitlyn Mayer	Charleston Oyster Farm	caitlyn@charlestonoysterfarm.com
David Belanger	Shellfish grower	dave@clammerdave.com
Debra Hernandez	SECOORA	debra@secoora.org
Drew Edwards	SC DHEC	edwardaj@dhec.sc.gov
Ed Atkins	Gullah/Geechee Fishing Association	
Emily Cedzo	Coastal Conservation League	emilyc@scccl.org
Erik Smith	USC and North Inlet - Winyah Bay NERR	erik@belle.baruch.sc.edu
Erik Sotka	College of Charleston	sotkae@cofc.edu
Evan Sherer	N/A	evansherer23@gmail.com
Gregory Sorg	SC DNR, Shellfish Research Section	sorgg@dnr.sc.gov
Joy Brown	The Nature Conservancy	joy_brown@tnc.org
Kelly Thorvalson	South Carolina Aquarium	kthorvalson@scaquarium.org
Kim Jones	Town of Bluffton	kjones@townofbluffton.com
Kwame Sha	Gullah/Geechee Fishing Association	
Marcus Austin	SC DNR	austinm@dnr.sc.gov
Matthew Baumann	SC DHEC	baumanms@dhec.sc.gov
Peter Bierce	Oyster Grower	peter@charlestonoysterfarm.com
Queen Quet	Gullah/Geechee Sea Island Coalition	GullGeeCo@aol.com
Scott Noakes	The University of Georgia	snoakes@uga.edu
Susan Lovelace	South Carolina Sea Grant Association	susan.lovelace@scseagrant.org
Thomas Bierce	Charleston Oyster Farm	thomas@charlestonoysterfarm.com
Blaik Keppler	SC DNR, ACE Basin Coastal Training	KepplerB@dnr.sc.gov
Lauren Zentner	Charleston Waterkeeper	zentnerla@g.cofc.edu

APPENDIX III: DISCUSSION QUESTIONS AND FRAMING IDEAS

Discussion 1: What water quality changes are we seeing, and how might they be interacting with acidification?

- What changes are we seeing over time?
- What are the highest priority issues facing stakeholders right now? How does acidification fit into this? Considering minimal monitoring, might acidification be linked with some of these existing changes we already know about?
- Who is addressing these changes and how are they addressed?
- How do you incorporate water quality information into your work?
- What tools do you use to access this information and what tools would be helpful in moving forward?

Discussion 2: Managing risk: shellfish, acidification and how to prioritize monitoring

- How would monitoring for acidification parameters fit into the existing monitoring efforts?
- What acidification monitoring would be sufficient? What is possible?
- Would a public-private monitoring or research partnership be helpful? What might one look like?
- How does the issue of acidification impact any local, state or federal water quality regulations? Other regulatory measures?
- Even if the threat of coastal and ocean acidification in SC/GA was completely known, what amount of impact to you and your line of work is acceptable?
- Let's choose 2 priority sites for monitoring and brainstorm the partnerships and potential funding opportunities to execute this monitoring
- If not sufficiently discussed in #1, what tools do you currently use, if any, to assess water quality and could acidification data be incorporated into these tools?

Discussion 3: Next steps: Needs, opportunities, and partnerships in South Carolina and Georgia

- Where do you want to see the coastal and estuary resources of SC/GA in 10-20 years? What characteristics do you envision?
- How do you see yourself playing a role in making that happen with others?
- What recommendations do you have moving forward for either scientists, policy-makers, resource managers, industry or advocacy groups?
- How would you like to stay updated on this issue?